



Using Iridium's 9601 Transceiver on CubeSats

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What is FSGC?

- The Florida Space Grant Consortium (FSGC) was started in 1989 as part of NASA's National Space Grant College and Fellowship Program.
- The FSGC offers:
 - Fellowships to Graduate Students at Florida Universities/Colleges
 - Funding for Space related research
 - Funding for Pre-College Activities to increase the interest in the Space program
- The FSGC host the Florida University Satellite (FUNSAT) Design Competition.

What is FUNSAT?

- FUNSAT is a satellite design competition hosted by the FSGC
- It is open to students at all Florida Universities (both state and private schools)
- The satellites need to conform to the CubeSat standard developed by California Polytechnic State University and Stanford University
- Florida International University's entry for FUNSAT IV is called the PicoPanther

Cubesats

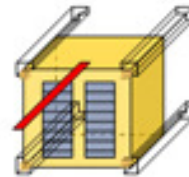
- 10cm³
- Launched on P-POD

P-POD Allocations for Dnepr L1 Campaign

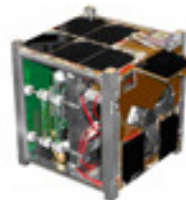
P-POD E

Apogee (km)	Perigee (km)	Period (sec)	Eccentricity
616.2	504.9	5752.1	0.0080

Deployment Time (After Liftoff)	$t_0 + 911.500 \text{ sec.}$
Upper Stage Velocity Magnitude	7640.3 m/s
Initial CubeSat Cluster Velocity Magnitude	7638.1 m/s
Insertion Altitude	505.9 km



**University of Hawaii
Voyager**
Downlink 437.405 MHz
1200 bps FSK, 500 mW
Downlink 2 5.84 GHz, 1 mW



**Cornell University
ICE Cube 2**
Downlink 437.425 MHz
9600 bps FSK (AX.25), 1W



**Cal Poly
CP1**
Downlink 436.845 MHz
15 bps DTMF, 500mW

Calpoly developer site

Florida International University

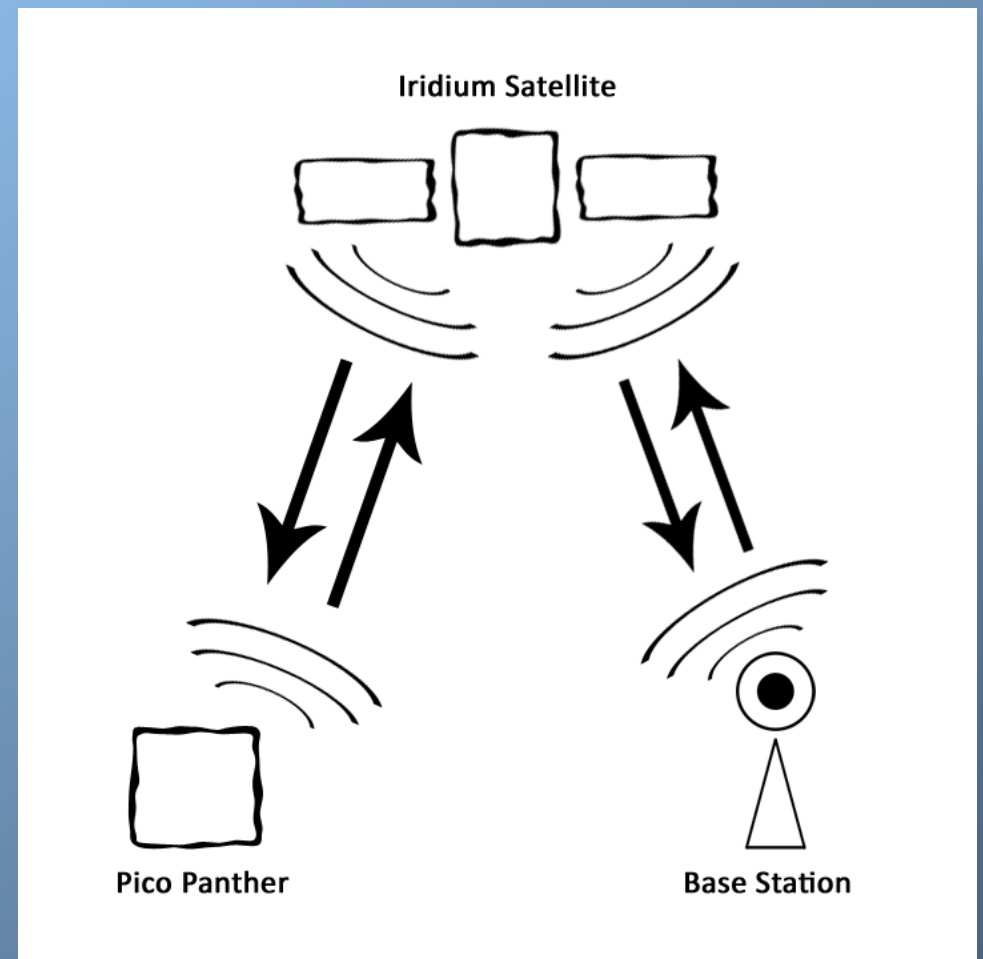
- FIU is a public research university established in 1965 and located in Miami, FL.
- The university is comprised of 16 colleges and schools, offering over 200 programs of study and 280 majors
- FIU is called home by more than 38,000 students, and more than 150,500 alumni world wide
- In 2007, FIU entered the satellite design world by competing in the FUNSAT IV Design Competition.

Introduction

- By using the Iridium constellation as a gateway, it is possible to communicate with an earth station from space.
- Twice a day 15 minute communication windows will be greatly increased. Near real time communication is possible.
- This method works because the Iridium constellation is at a slightly higher orbit than FUNSAT's CubeSats.

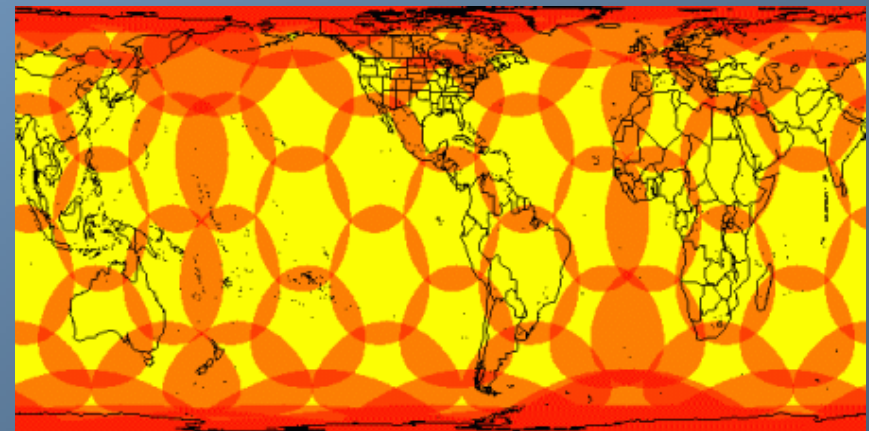
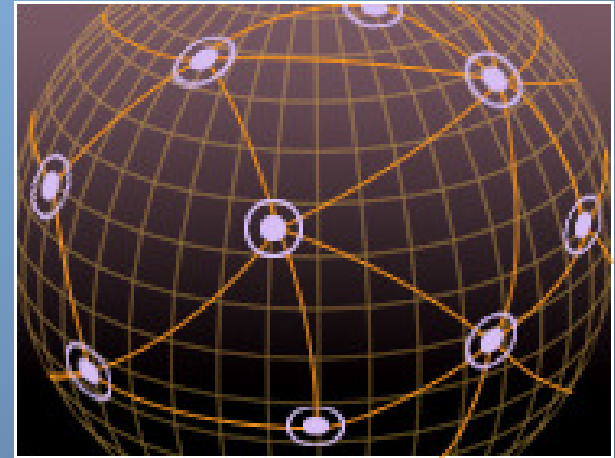
Iridium Network

- 66 satellites
- Inclination 86.4
- Altitude 780km
- L band
- Short Burst Data method
- 135-205 Bytes per message



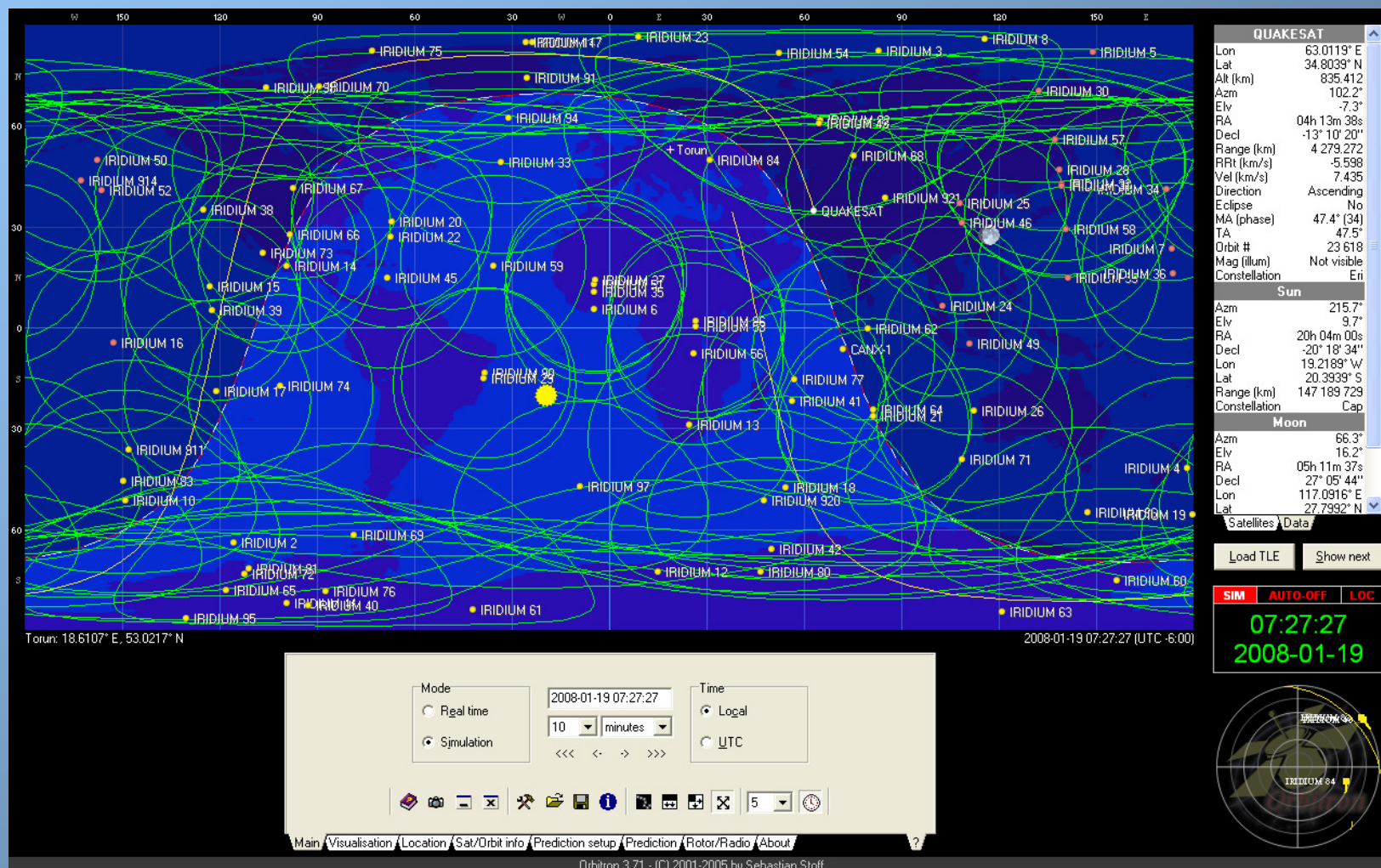
Iridium Network

- Global ground coverage
- More coverage in poles than equator
- Requires monthly subscription
- Messages received and sent via email client.



Iridium Network

Iridium Ground Plot Coverage using Orbitron, a ham radio resource for tracking satellites. A CanSat using Iridium is also plotted.



Doppler Effect

- Doppler shifts happen when there is a relative velocity present between a source and destination and as a result there is a perceived frequency shift in a signal.
- The equation that relates a Doppler shift for a speed of light transmission such a radio is:

$$F' = F + \frac{FV_{t/r}}{C},$$

$$V_t = V_r + V_{t/r}$$

Doppler Effect

- **1. Calculations for an earth transceiver and an Iridium satellite.**
- Frequency range of Iridium 9601: 1616 MHz – 1625 MHz
- Velocity of Iridium satellite at 780 km: 7.46 km/s
- Velocity of Earth: 465 m/s or .465 km/s
- Relative velocity in same direction: 6.995 m/s
- Relative velocity in opposite direction: -7.925 m/s
- Change in frequency in same direction @ 1625 MHz: **+37.88 kHz**
- Change in frequency in opposite @ 1625 MHz: **-42.927 kHz**
- Note: Iridium transceiver can accommodate +/- 37.5 kHz swing inherently.

Doppler Effect

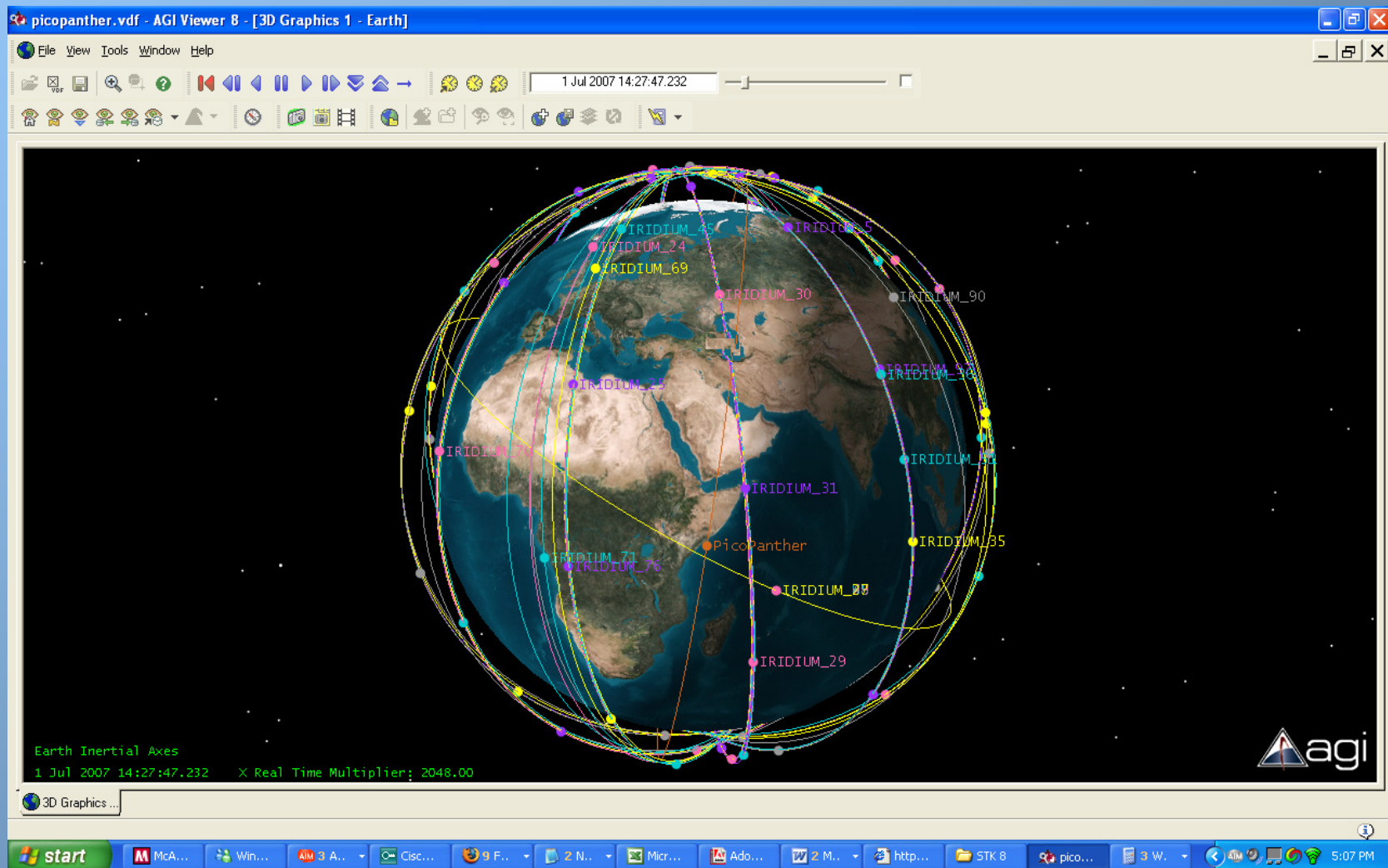
- **2. Calculations for a space based transceiver and an Iridium satellite.**
- Frequency range of Iridium 9601: 1616 MHz – 1625 MHz
- Velocity of Iridium satellite at 780 km: 7.46 km/s
- Velocity of Cube Sat at 700 km: 7.51 km/s
- Relative velocity in same direction: .05 km/s
- Relative velocity in opposite direction: -14.97 m/s
- Change in frequency @1625 MHz: **270 Hz**
- Change in frequency @1625 MHz: -81.087 kHz *Never occurs.

Simulation

- AGI STK provides a toolkit for real life simulation of a wide variety of products.
- One such product is satellites. STK allows for viewing multiple orbits, interactions, ground tracks and base station contacts.
- STK also models effects such as attenuation due to clouds and rain.
- Drawback: STK costs \$20,000 and upwards.
- A one week trial license is available.

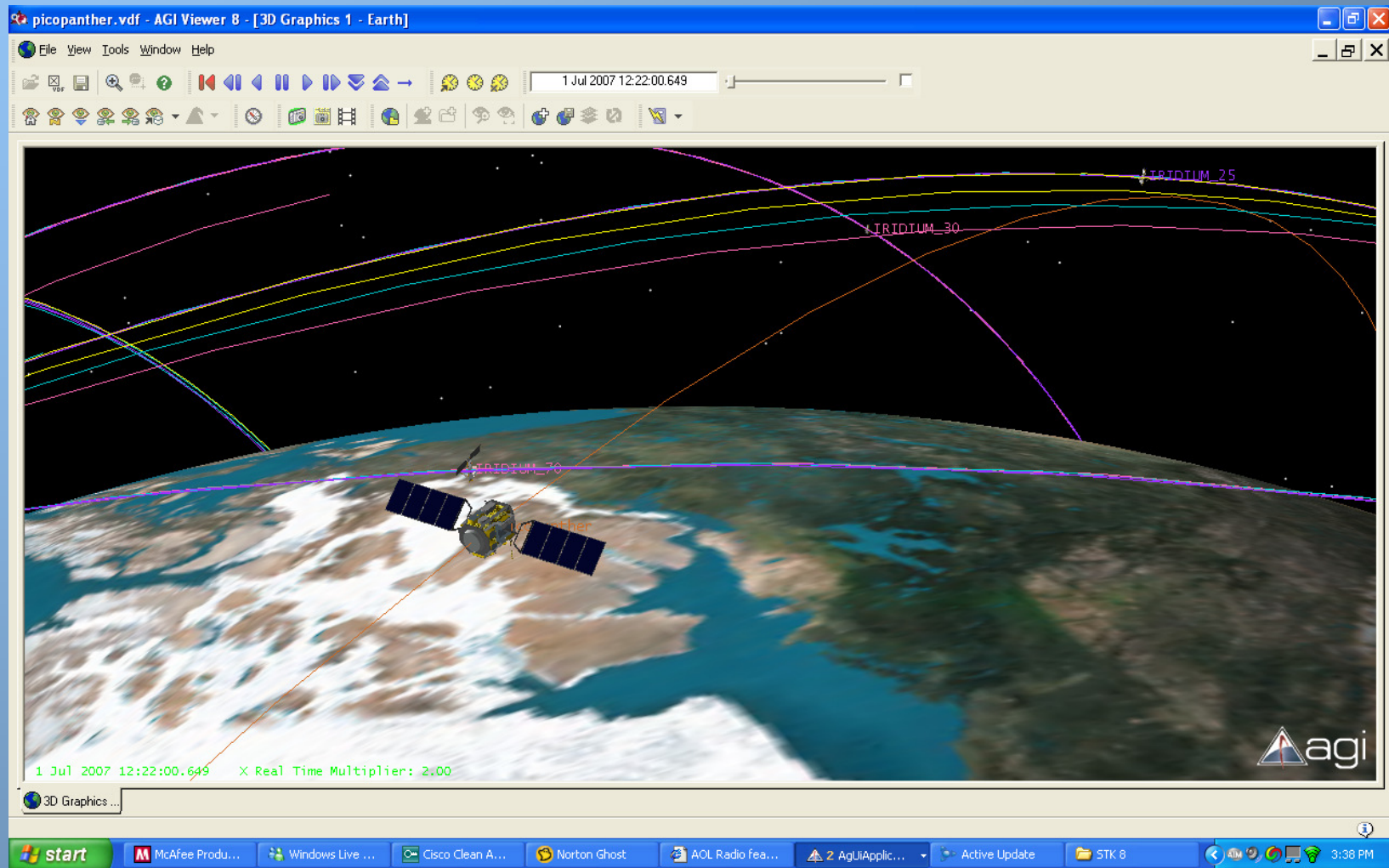
Simulation

STK simulation of PicoPanther and Iridium to find blackout zones. These zones last at most 15 minutes, mainly in equatorial regions.



Simulation

Close up of intercepting orbits used to find frequency of contacts.



Development

- A 9601 Transceiver
- An L band antenna
- A dsPIC MCU
- RS-232 capability
- C language compiler
- Coded library of basic functions
- Minor modifications



Development



Iridium Transceiver outside of case.

Development



Development environment for dsPic

Mass & Power

- Transceiver without case 200 grams
- Board is approximately 2 grams
- **Total Weight is 202 grams.**

Device Name	Voltage Max	Current Max
dsPic Controller	5V	40mA
Iridium transceiver	5V	1.5A
Total:	5V	1.54A

Budget

Parts	Cost
Standalone dsPIC board and cabling	\$80
Iridium transceiver	Already have
Programmer	Already have
Total for parts:	\$80

Since most of the part have been bought, the total flight model would be \$80 dollars in hardware plus a subscription/data plan of choice.

Subscription

Subscription	Cost
Iridium monthly cost	16.00
10 bytes every hour @ .0015	\$10.80 per month
Total subscription:	\$26.80 per month

Subscription	Cost
Iridium monthly cost	16.00
256 bytes every hour @ .0015	\$276 per month
Total subscription:	\$292.00 per month

This slides illustrates the significant price difference in data transmission styles. A user wishing to send 10 bytes an hour will pay 26.80 per month whereas a user sending 256 bytes an hour will send \$292 per month.

Subscription

- An unsigned integer is one byte.
- Having a ten byte an hour plan, a user can send status data that uses binary representation to show levels of radiation, VLF transmission intensities, and other information.
- 2^{10} , or 1024 levels could be used to represent data in a 10 byte format. More than enough resolution to understand measured information.
- Creative data plans can cut costs and increase frequency of transmission in missions that would like to use the Iridium network for polling of environment.
- Real time alerts of exceeded threshold values is the cheapest use of Iridium.

Final Model

- Create a custom board on campus for free.
- Use smaller 16 pin dsPIC instead of current chip.
- Create functionality so the FM can be used in a server-client relationship, as opposed to standalone. This would be useful for future CubeSats using this module.

Server-Client Concept

- Discrete pin would turn on and off a Server-Client relationship allowing another MCU to just send raw serial data and our module would take care of formatting the command and sending.
- Network feedback and data reception would be decoded and sent via serial.
- This concept would allow a serial based “plug and play” interaction with a module.

Conclusion

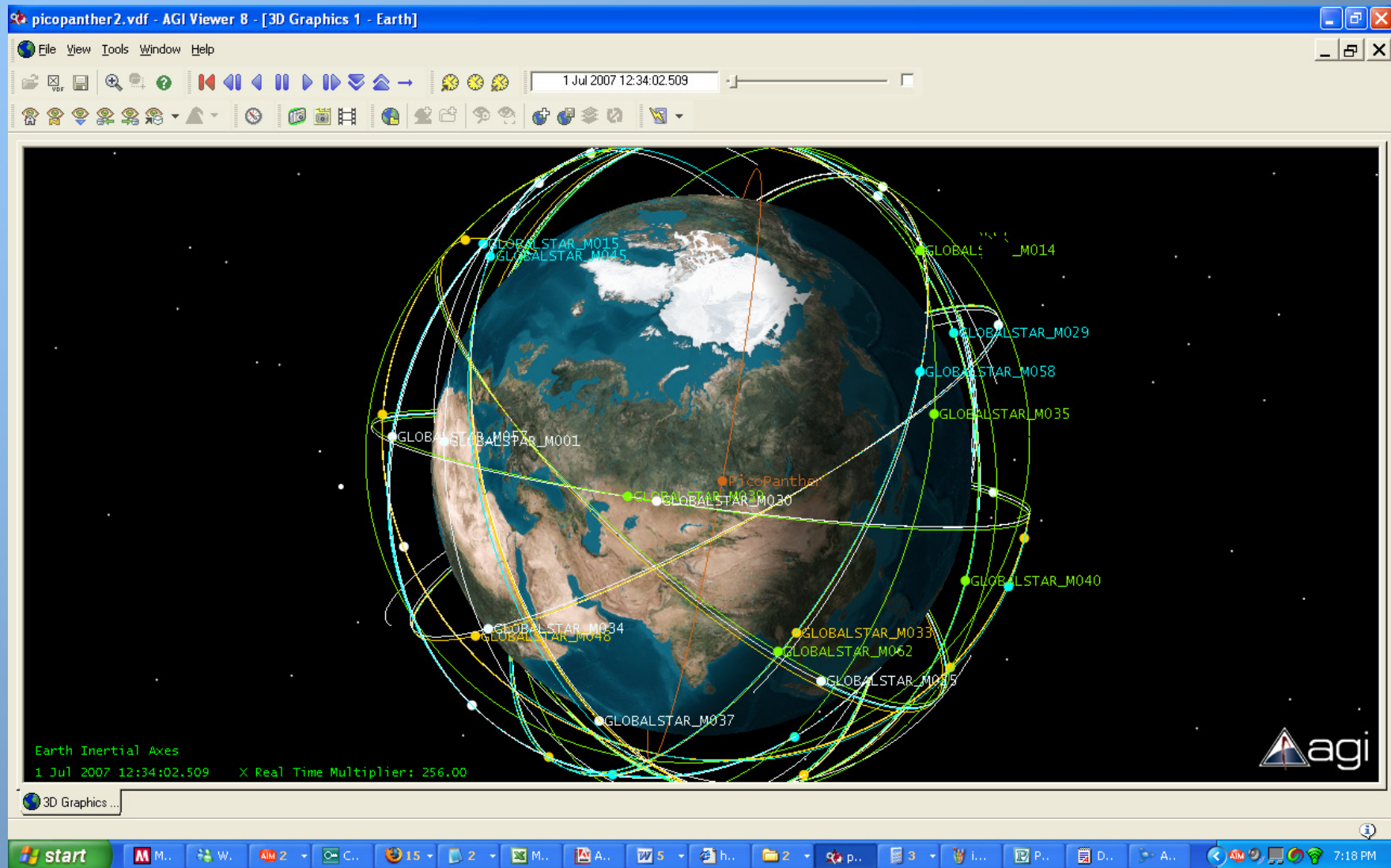
- Iridium can be used in amateur satellites theoretically, but should be proven in practice.
- Use of the network is only costly if the user wishes to transmit large quantities of data.
- In the event a user wishes to move large quantities of data, the larger 9522 transceiver with FTP capability should be used. No per byte charges using FTP.

Alternatives

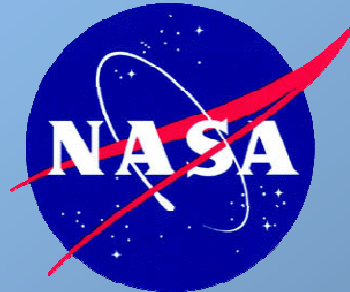
- GlobalStar can be used for CubeSats in certain areas.
- Doppler shifts are higher and network is less reliable in polar regions. DSP functions of the dsPIC could be used to compensate doppler shift.
- Less backing of their data transceiver.
- Cheaper plans.

Alternatives

STK simulation of orbital interaction with GlobalStar



Team Pico Panther would like to thank the following:



- Dr. Kenneth G Furton, Dean College of Arts and Sciences for his continued support in establishing FUNSAT at FIU.
- NASA for its dedication to student research programs and the advancement of science.
- FSGC for giving Florida students the opportunity to design and implement satellite technology.
- AMSAT for developing and supporting amateur satellites everywhere and providing a forum for the exchange of ideas and advancement of amateur satellites.